NAGADI

# NAGADI REPORT

**100MLD Capacity Sewage Treatment Plant at Mailasandra, Bengaluru**.


| | | page no. |
|---|---|---|
| 1. | Executive Summary | 1 and 2 |
| 2. | Introduction | 3 |
| 3. | Authority | 3 |
| 4. | Project Details | |
| | The Site | 3 and 4 |
| | The Structure | 4 |
| | Seismic Zone | 4 |
| 5. | Object and Scope of Work | 4 to 6 |
| 6. | Programme of Investigations | |
| | Field Investigations | 6 to 10 |
| | Lab Investigations | 10 and 11 |
| 7. | Results & Analysis of Investigations | 11 to 19 |
| 8. | Design Criteria & Recommendations | 20 to 27 |
| 9. | Limitations | 28 |
| 10. | Appendix-A | 29 and 30 |
| 11. | Appendix-B | 31 |

| | | |
|---|---|---|
| 12. | Appendix-C | 32 to 34 |
| 13. | List of IS Codes–Appendix-D | 35 and 36 |
| Tables | | |
| | Soil/Rock Profile Tables | 1 to 4 |
| Figures | | |
| | Site Plan | 1 |
| | Compiled Soil/Rock Profile | 2 |
| | Grain Size Analysis Curve | 3a & 3b |
| | N– values Curve | 4 |
| | Earth Resistivity Curve | 5 |

**G(B)12788 - GEOTECHNICAL INVESTIGATION REPORT for the Proposed 100MLD Capacity Sewage Treatment Plant at Mailasandra, Bengaluru.**

## *EXECUTIVE SUMMARY*

M/s Toshiba Water Solutions Private Limited, House No.2, 1st Cross, Aashirwad, Sai Enclave, KSR Main Road, Kanakagiri, Banjara Layout, Horamavu, Bengaluru - 560043 propose to upgrade/augment the capacity of the existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru.

Undulations had been observed across the complete site. Maximum level difference of about 5.2m had been observed within the site as per the topographical survey drawing. Existing buildings/water retaining structures are located within the site. Vegetation in the form of grass, trees, etc., had been observed within the site during the period of field investigations.

The proposed structures consist of Receiving Chamber, Manual Coarse Screen Channel, Mechanical Coarse Screen Channel, Wet Well + Pumping Station, Disc Filter Inlet Channel,Disc Filter Building, Disc Filter Outlet Channel, DGRIT Chamber, New DG Set for 26 MLD TSPS, New Power Transformer, DG Set, Chorine Leak Absorption System.

For obtaining the required parameters for the design of the foundations of the proposed structures, geotechnical investigations had been undertaken at the site which consisted of progressing four boreholes from the existing ground level down to a depth of 10m.

The borehole investigations indicate that the filled up soil had been encountered from the existing ground level down to depths varying from 2.2m to 6.8m. The fill contains soil, debris, boulders, etc. Filled up soil was not encountered at the location of borehole BH4.

The virgin subsoil encountered at the site is clayey silty sand to silty clayey sand underlain by strata of clayey silty sand to silty sand with clay and gravel. The colour of the subsoil varies from brownish grey to reddish brown with yellow at shallow depths to yellowish white with grey brownish yellow with white at larger depths.

As Refusal/Rock Strata had been encountered at depths varying between 3.2m and 7.8m below existing ground level, drilling by rotary drilling machine using Nx Size diamond bits had been carried out in refusal/rock strata in all the boreholes down to about 10m depth in the refusal/rock strata, to ensure that adequate information regarding the refusal/rock strata is obtained.

The observed N-values (N:9-28) evaluated from the Standard Penetration Tests indicate that the filled-up soil encountered at the site is observed to be in a loose to medium dense state down to depths varying from 2.2m to 6.8m below the existing ground level. The high N-values recorded in the filled up soil are due to presence of debris, gravels, cobbles, etc.

The observed N-values (N:12-59) evaluated from the Standard Penetration Tests indicate that the virgin soil strata encountered below the filled up soil strata is in a medium dense to dense state down to the depths of the refusal/rock strata.

The rock strata consists of Granitic Gneiss in a completely weathered state and moderately weathered state to slightly weathered state with core recoveries ranging between 0% to 52% and RQD ranging between 0% to 52%, down to the maximum depth investigated.

The ground water table was encountered at depths of 4m and 8.2m below existing ground level in the boreholes BH2 and BH3 respectively, at the time of investigation carried out in the month of May, 2023. Water table can be expected to rise further by the end of the rainy season. Water table was not encountered in the boreholes BH1 and BH4.

Considering the substrata conditions, type of the structures and envisaged loadings, Shallow Foundations are recommended for the proposed structures.

The recommendations are given in the Article no.9 of this report.

## *1.0 INTRODUCTION*

1.1 M/s Toshiba Water Solutions Private Limited, House No.2, 1st Cross, Aashirwad, Sai Enclave, KSR Main Road, Kanakagiri, Banjara Layout, Horamavu, Bengaluru - 560043 propose to upgrade / augment the capacity of the existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru.

1.2 To design the substructures for the proposed additional structures for the Sewage Treatment Plant, adequate information regarding the substrata conditions is required. For this purpose, detailed geotechnical investigations had been undertaken.

1.3 This report contains the details of the geotechnical investigations conducted along with the results and analysis of the investigations and recommendations.

1.4 Geotechnical investigations for this purpose had been carried out as per the authorization of Work Order No: TWS/WO/232420077/BWSSB-Mailasandra (100 MLD) Bengalore dated 26th April, 2023, issued by M/s Toshiba Water Solutions Private Limited, House No.2, 1st Cross, Aashirwad, Sai Enclave, KSR Main Road, Kanakagiri, Banjara Layout, Horamavu, Bengaluru - 560043.

## *2.0 PROJECT DETAILS*

### 2.1 Site Location

The site is located within the existing premises of BWSSB 75MLD Sewage Treatment Plant at Mailasandra, Bengaluru.

### 2.2 Site Layout and Topography

2.2.1 A schematic site plan showing the dimensions and other details of the site is enclosed in this report (fig.1).

2.2.2 Undulations had been observed across the complete site. Maximum level difference of about 5.2m had been observed within the site as per the topographical survey drawing.

2.2.3 Existing buildings/water retaining structures are located within the site.

2.2.4 Vegetation in the form of grass, trees, etc., had been observed within the site during the period of field investigations.

**2.3 The Structure**

2.3.1 The proposed structures consist of :

a) Receiving Chamber

b) Manual Coarse Screen Channel

c) Mechanical Coarse Screen Channel

d) Wet Well + Pumping Station

e) Disc Filter Inlet Channel

f) Disc Filter Building

g) Disc Filter Outlet Channel

h) DGRIT Chamber

i) New DG Set for 26 MLD TSPS

j) New Power Transformer

k) DG Set

l) Chorine Leak Absorption System.

**2.4 Seismic Zone**

The present site is located in the Seismic Zone II, as per the seismic zoning map of India given in BIS code IS : 1893, Part 1 - 2016.

***3.0 OBJECT OF INVESTIGATIONS***

3.1 For designing the foundation system of the proposed structures, the following data are required :

a) Type of foundation

b) Depth below the ground level at which the foundation system is to be laid.

c) Allowable bearing pressure at the foundation level.

3.2 To determine the above factors, the following information would be required:

a) The subsoil/rock profile indicating thicknesses of the various soil/rock strata, to a depth within the influence zone below the foundations

b) Engineering properties of the soil/rock strata at various levels

c) Physical characteristics of the soil/rock strata

d) Variation of strength of soil/rock strata with depth.

3.3 For evaluating the above parameters, field investigations and laboratory investigations on the soil/rock samples collected during the field investigations, have been carried out.

3.4 The results from these investigations have been analysed to provide the recommendations for the design of foundations.

## *4.0 SCOPE OF INVESTIGATIONS*

4.1 The scope of investigations as stipulated by the client consists of :

a) Conducting boreholes in soil strata down to 10m depth below existing ground level at four (4) locations.

b) Drilling to a minimum depth of 5m in refusal/rock strata to be carried out if the refusal/rock strata is encountered in the boreholes.

c) Conducting Earth Resistivity Test at one location.

d) Conducting Field Permeability Test at one location.

e) Conducting Field Percolation Test at one location.

f) Excavating Trial Pit down to a maximum depth of 1.5m below the existing ground level at one location.

g) Conducting relevant laboratory tests on soil/rock samples recovered.

h) Preparation and submission of a technical report in two copies containing the details of the tests carried out, their analysis and recommendations regarding the foundation system to be adopted.

4.2 The following operations were to be undertaken while progressing the boreholes:

a) Conducting standard penetration tests at regular intervals in soil strata.

b) Recovering undisturbed soil samples from various levels of the subsoil strata.

c) Recovering rock core samples in rock strata.

d) Recording ground water table levels, if met with.

## *5.0 FIELD INVESTIGATIONS*

### 5.1 Preliminary Details

Field investigations had been carried out from 4th to 13th May, 2023. The weather was clear and sunny at the time of investigations.

### 5.2 Boreholes

5.2.1 Four (4) boreholes designated as BH1 to BH4 were progressed from the existing ground level by using Rotary Drilling Rig to study the substrata conditions at the site.

5.2.2 Refusal/rock strata had been encountered at varying depths in all the boreholes.

5.2.3 Drilling in refusal/rock strata had been carried out in all the boreholes so as to ensure that adequate information regarding the refusal/rock strata below the likely foundation level is obtained.

5.2.4 Drilling in refusal/rock strata had been carried out down to a minimum depth of 5m in the refusal/rock strata, by rotary drilling rig using diamond bits of Nx size.

5.2.5 The depths at which refusal strata / rock strata had been encountered in each borehole along with the termination depths of each borehole are given below:

| Structures | BH No. | RL(m) of the Ground | Depth (m) of Refusal Strata below E.G.L | Termination Depth (m) below E.G.L |
|---|---|---|---|---|
| Receiving Chamber, Coarse Screen Channel, DGRIT Chamber, Chlorine Leak Absorption System, Wet Well & Pumping Station | BH1 | 92.7 | 3.2 | 8.2 |
| DGRIT Chamber, New DG Set for 26MLD TSPS, New Power Transformer | BH2 | 94.6 | 5.7 | 10.7 |
| Chlorine Leak Absorption System, Disc Filter | BH3 | 93.8 | 7.8 | 12.8 |
| DG Set, | BH4 | 97.9 | 4.8 | 10.8 |

*E.G.L : Existing Ground Level*

5.2.6 Standard Penetration Tests had been conducted in soil strata at regular intervals. Disturbed soil samples recovered from split spoon samplers had been retained for identification purposes.

5.2.7 Standard Penetration Test had also been conducted in completely weathered rock strata for the confirmation of refusal/rock strata.

5.2.8 Undisturbed soil samples had been recovered by thin walled tube samplers conforming to IS : 2132.

5.2.9 Soil/rock samples had been transported to the laboratory for testing purposes.

**5.3 Ground Water Table**

Ground water table was encountered at depths of 4m and 8.2m below existing ground level in the boreholes BH2 and BH3 respectively, at the time of investigation carried out in the month of May, 2023. Water table can be expected to rise further by the end of the rainy season. Water table was not encountered in the boreholes BH1 and BH4.

## 5.4 Trial Pit

One (1) no. of Trial Pit was excavated at the specified location. The trial pit has been designated as TP1. Trial Pit of size 1.5m x 1.5m in plan, was excavated down to about 1.5m depth below existing ground level as per scope of work. Disturbed and Undisturbed soil samples were collected from the trial pit for conducting relevant laboratory tests.

## 5.5 Earth Resistivity Test

5.5.1 One Earth Resistivity Test has been carried out at the specified location. The Earth Resistivity Test has been designated as ERT1. This test has been conducted using Wenner's four pole electrode method as per IS:3043.

5.5.2 In this test, four electrodes had been driven into the ground surface along a straight line at equal intervals. The tests involves the passing of a current through the outer two electrodes called the current electrodes and the measurement of the voltage difference between the two inner electrodes called the potential electrodes. The ratio of the voltage difference measured to the current passed gives the resistance. An electrical megger had been used to determine the resistance directly at the site. The resistance had been so determined for various electrode spacings.

5.5.3 The above procedure had been repeated for eight different directions at selected location, as per the standard procedure.

5.5.4 As existing buildings/structures are located in North-East, South-East and South-West directions, the test had been carried out only up to a distance of about 3m in North-East direction and up to 5m in South-East and South-West directions.

5.5.5 The earth resistivity of the soil which is a function of the resistance determined is calculated for each electrode spacing used.

5.5.6 The earth resistivity so determined for each direction is plotted on a polar plot to obtain a closed curve. The representative earth resistivity for the test location is then determined as the radius of the circle having an area equivalent to the enclosed area within the closed curve of the polar plot.

5.5.7 The earth resistivity of the soil depends on the density, water content, grain size distribution etc. of the soil.

**5.6 Field Permeability Test**

5.6.1 Field Permeability Test was conducted in soil strata by Falling Head Method using open ended casing method at one location.

5.6.2 This test was carried out at 3m depth below the existing ground level at the specified test location.

**5.7 Percolation Test**

5.7.1 One (1) no. of Percolation test was carried out as per IS 2470-2: Code of practice for installation of septic tanks, Part II (Appendix A, Clause 5.1). The percolation test has been designated as PT1.

5.7.2 The percolation test was conducted by excavating a pit of size 1.5m x 1.5m down to a depth of 1.5m. At the bottom of this pit, further excavation of 0.30m x 0.30m was carried out to a depth of 0.30m. All the loose material shall be removed from the hole and coarse sand or fine gravel was added to protect the bottom from scouring and sediment.

5.7.3 Water shall then be poured up to a minimum depth of 300 mm over the coarse sand/gravel. In order to ensure that the soil is given ample opportunity to swell and to approach the condition it will be in, during the wettest season of the year, the percolation shall be determined 24 hours after the water is added. Then from fixed reference point the drop in water level shall be measured at 30 minutes intervals for 4 hours. This drop shall be used to calculate the percolation rate.

5.7.4 The drop that occurs during the final 30 minutes period shall be used to calculate the percolation rate. The drops during prior periods provide information for possible modification of the procedure to suit local circumstances.

5.7.5 Based on the final drop, the percolation rate, that is, the time in minutes required for water to fall 25 mm, shall be calculated.

## *6.0 LABORATORY INVESTIGATIONS*

### 6.1 Tests on soil and rock samples from boreholes

6.1.1 The soil samples brought to the laboratory had been subjected to various tests to determine the following properties:

a) Type of soil and its gradation

b) Consistency limits

c) Natural Bulk Density & Water Content

d) Strength parameters like cohesion, angle of shearing resistance

e) Settlement Characteristics.

6.1.2 In order to determine the above properties, the following tests have been conducted:

a) Sieve analysis on coarse grained soil fraction

b) Hydrometer analysis on fine grained soil fraction

c) Liquid Limit and Plastic Limit tests

d) Natural Density and Water Content determination tests

e) Triaxial Tests

6.1.3 The rock samples brought to the laboratory are typically subjected to various tests to determine the following properties:

a) Unit weight

b) Porosity

c) Water absorption

d) Unconfined compressive strength tests

e) Point load index strength tests.

**6.2 Chemical Analysis**

The soil and water samples collected from the boreholes had been tested to determine the pH-value and the presence of salts harmful to reinforced cement concrete construction namely Chloride and Sulphate contents.

## *7.0 RESULTS & ANALYSIS*

**7.1 Presentation of Results**

7.1.1 The results of the borehole investigations and of the laboratory investigations conducted on the soil/rock samples collected from the boreholes have been presented in the form of soil profile tables and rock profile tables.

7.1.2 The soil profile tables indicate the following :

a) Standard Penetration Test values (N-values) at various depths

b) Description identifying the type of soil and rock

c) Grain size analysis indicating composition of subsoil

d) Consistency limits

e) Natural Density and Water Content

f) Triaxial Test results.

7.1.3 The rock profile tables indicate the following :

a) Strata description identifying the type of rock strata

b) Number of core pieces of different sizes and thereupon the core recovery

c) Rock Quality Designation (RQD)

d) Rock properties like unit weight and water absorption.

e) Unconfined compressive strength

f) Point load strength.

## 7.2 Soil and Rock Profile

7.2.1 A perusal of the data presented in the soil and rock profile tables indicates the presence of the following four soil/rock strata at the site :

a) Stratum - I : Filled up soil with boulders, debris, etc. The colour of the strata is brown with grey to reddish brown.

b) Stratum - II : Clayey silty sand to silty clayey sand. The colour of the strata is brownish grey to reddish brown with yellow.

c) Stratum - III : Clayey silty sand to silty sand with clay and gravel. The colour of the strata varies from yellowish white with grey brownish yellow with white.

d) Stratum - IV : Blackish grey, grey and white Granitic Gneiss Rock.

7.2.2 The thickness of the four strata in the boreholes are as follows :

| Borehole No. | Strata (Depth in m : from - to) | | | |
|---|---|---|---|---|
| | Stratum-I | Stratum-II | Stratum-III | Stratum-IV |
| BH1 | 0.0 - 2.2 | 2.2 - 2.8 | 2.8 - 3.2 | 3.2 - 8.2 |
| BH2 | 0.0 - 2.7 | 2.7 - 4.7 | 4.7 - 5.7 | 5.7 - 10.7 |
| BH3 | 0.0 - 6.8 | N.E | 6.8 - 7.8 | 7.8 - 12.8 |
| BH4 | N.E | 0.0 - 3.2 | 3.2 - 4.8 | 4.8 - 10.8 |

*N.E : Not Encountered*

7.2.3 The above results show that :

a) Stratum - I consisting of filled up soil had been encountered from the existing ground level down to depths varying from 2.2m to 6.8m. The fill contains soil, debris, boulders, etc. Filled up soil was not encountered at the location of borehole BH4.

b) Stratum - II consisting of mixed soils, with varying percentages of sand, silt and clay had been encountered from the existing ground level/underlying Stratum - I and extending down to a maximum depth of about 4.7m.

c) Stratum - III consisting of predominantly sandy soils, with significant percentage of silt and low percentage of clay had been encountered underlying Stratum - I/ Stratum - II and extending down to the depths of refusal/rock strata.

d) Stratum - IV consisting of Granitic Gneiss rock, had been encountered underlying Stratum - III at depths varying between 3.2m and 7.8m below the existing ground level and extending down to the maximum investigated depth of 12.8m below the existing ground level.

**7.3 Soil Composition**

7.3.1 The grain size distributions of the soil samples in the boreholes have been presented in the form of grain size analysis curves in figs.3a and 3b.

7.3.2 The variations in the grain size distributions of the soil in each of the strata in the boreholes are as follows:

a) Stratum - II : Clayey silty sand to silty clayey sand

| BH No. | Gravel (%) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|
| BH1 | 0 | 52 | 32 | 16 |
| BH2 | 0 | 42 | 27 | 31 |
| BH3 | | N.E. | | |
| BH4 | 0 | 46 - 48 | 27 | 25 - 27 |

*N.E : Not Encountered*

b) Stratum - III : Clayey silty sand to silty sand with clay and gravel

| BH No. | Gravel (%) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|
| BH1 | 0 | 49 | 28 | 23 |
| BH2 | 20 | 62 | 12 | 6 |
| BH3 | 0 | 66 | 20 | 14 |
| BH4 | 0 | 49 | 35 | 16 |

7.3.3 The above results indicate that the soil in :

a) Stratum -II consists of about 42 - 52% of sand, 27- 32% of silt, 16 - 31% of clay and 0% of gravel.

b) Stratum - III consists of about 49 - 66% of sand, 12 - 35% of silt, 6 - 23% of clay and 0 - 20% of gravel.

**7.4 Natural Density and Water Content**

7.4.1 The variations in the natural bulk densities, water contents and dry densities of the soil samples collected in the boreholes, are as follows:

| BH. No. | Bulk Density ($g/cm^3$) | Water Content (%) | Dry Density ($g/cm^3$) |
|---|---|---|---|
| BH1 | 1.83 | 13.7 | 1.61 |
| BH2 | 1.93 - 1.94 | 12.6 - 14.7 | 1.68 - 1.72 |
| BH3 | 1.92 | 11.3 | 1.73 |
| BH4 | 1.92 - 1.97 | 10.4 - 15.2 | 1.67 - 1.79 |

7.4.2 The in-situ Dry Density of the subsoil ranges between 1.61$g/cm^3$ and 1.79$g/cm^3$ and the Natural Water Content varies between 10.4% and 15.2%.

7.4.3 The above results indicate that the subsoil is in a medium dense to dense state down to the depths of refusal/rock strata.

**7.5 Consistency Limits**

7.5.1 The variations in the results of the consistency limits tests conducted on the soil samples are as follows:

Liquid Limit : 25% to 36%

Plastic Limit : Nil to 23 %

Plasticity Index : Nil to 15%.

7.5.2 The consistency limits indicate that the soil encountered is medium plastic to non plastic down to the depths of refusal/rock strata.

**7.6 Triaxial Test Results**

The angle of shearing resistance (N) of the subsoil as determined from triaxial tests, ranges between $24^0$ and $29^0$ and the cohesion (c) values of the subsoil varies between $0.12kg/cm^2$ and $0.16kg/cm^2$.

**7.7 Standard Penetration Test Values (N-values)**

7.7.1 The N-values are presented in tables. 1 to 4 and in the compiled soil/rock profile in fig.2. The N-values have also been plotted with respect to depth in fig.4.

7.7.2 The observed N-values (N:9-28) evaluated from the Standard Penetration Tests indicate that the filled-up soil encountered at the site is observed to be in a loose to medium dense state down to depths varying from 2.2m to 6.8m below the existing ground level. The high N-values recorded in the filled up soil are due to presence of debris, gravels, cobbles, etc.

7.7.3 The observed N-values (N:12-59) evaluated from the Standard Penetration Tests indicate that the virgin soil strata encountered below the filled up soil strata is in a medium dense to dense state down to the depths of the refusal/rock strata.

7.7.4 In refusal/rock strata, high blow counts have been recorded for small depths of penetration of the SPT sampler, indicating that the completely weathered rock encountered below refusal is very hard and compact in-situ.

## 7.8 Chemical Analysis of Soil and Water

7.8.1 The results of the chemical analysis conducted on soil and water samples collected from different boreholes, for determining the presence of any harmful salts which can have adverse effects on construction, are as follows :

**a) Soil Samples**

| BH No. | Depth (m) | pH value | Chloride Content (%) | Sulphate Content (%) |
|---|---|---|---|---|
| BH3 | 4.5 | 6.92 | 0.023 | 0.036 |

**b) Water Samples**

| BH No. | pH value | Chloride Content (ppm) | Sulphate Content (ppm) |
|---|---|---|---|
| BH2 | 7.33 | 24.65 | 20.65 |

| *IS LIMITS* | |
|---|---|
| ***pH value*** | ***Not less than 6 (Refer IS 3025 Part 11- Table 1)*** |
| ***Chloride content (ppm)*** | ***Maximum 500 ppm (Refer IS 3025 Part 32- Table 2)*** |
| ***Sulphate content (ppm)*** | ***Maximum 400 ppm (Refer IS 3025 Part 24- Table 2)*** |

7.8.2 The above results indicate that the soil encountered at the site will not have any aggressive effect on normal concrete construction works.

## 7.9 Rock Conditions

7.9.1 An analysis of the data provided in the rock profile tables indicates the following :

a) The rock strata generally consists of Granitic Gneiss down to the maximum depth investigated.

b) The colour of the Granitic Gneiss rock is Blackish grey, grey and white down to the maximum depth investigated

c) Core recoveries have been observed to be ranging from 0% to 52% at different depths in different boreholes

d) RQD values have been observed to be varies between 0% to 52% at different depths in different boreholes

e) Unit weight of the rock varies between 1.91g/cm$^3$ to 2.82g/cm$^3$

f) Porosity of the rock varies between 0.10% to 3.01%

g) Water absorption of the rock varies between 0.01 % to 2.51%

h) The unconfined compressive strength of the rock is 1025kg/cm$^2$

i) Point load strength of the rock generally varies between 259kg/cm$^2$ and 1278kg/cm$^2$.

7.9.2 The above analysis of the rock conditions indicates that the Granitic Gneiss rock has been observed to be in Completely weathered state (recognized by nil core recovery and RQD), Moderately weathered state to Slightly weathered state (recognized by significant core recovery and RQD).

**7.10 Compiled Soil/Rock Profile**

7.10.1 An overview of the results and their analysis has been presented in the form of a compiled soil/rock profile in fig.2.

7.10.2 The above figure shows the various strata encountered and their thicknesses in each of the boreholes and also gives the soil and rock composition and the observed N-values at various depths in various boreholes.

**7.11 Earth Resistivity Test**

7.11.1 The results of the Earth Resistivity Test has been analysed as given below.

7.11.2 The earth resistivity is calculated using the following expression :

$$\rho = 2 \cdot \pi \cdot S \cdot R$$

where, D = resistivity of the soil in S-m

S = spacing of electrodes in m

R = measured resistance or megger reading in S.

7.11.3 The earth resistivity value for each of the eight directions in which the test is conducted is determined as the mean value of electrical resistivity of successive electrode spacings in a given direction.

7.11.4 As existing buildings/structures are located in North-East, South-East and South-West directions, the test had been carried out only up to a distance of about 3m in North-East direction and up to 5m in South-East and South-West directions.

7.11.5 The earth resistivities so determined for each direction are then plotted on a polar plot to obtain a polar resistivity curve. The area inside the polar resistivity curve is calculated and a circle of equivalent area is drawn. The radius of this circle gives the representative earth resistivity at the test location.

7.11.6 Polar diagrams for the earth resistivity test is given in fig.5. The earth resistivity value at the test location is given below :

| Earth Resistivity Test No. | Earth Resistivity (S-m) |
|---|---|
| ERT1 | 339.88 |

**7.12 Percolation Test**

7.12.1 One (1) no of Percolation Test was carried out in a pit of 1.5m depth. The Percolation Rate is the time in minutes, required for the water level to fall 25mm, based on the last 30 minutes of the test. The Percolation Rate is given below :

| Pit No. | Depth (m) | Percolation rate (min) |
|---|---|---|
| PT1 | 1.5 | 83.3 |

## 7.13 Field Permeability Tests

7.13.1 The coefficient of permeability 'k' is determined using the following expression :

$$k = \frac{\pi \cdot r}{5.5 \cdot (t_2 - t_1)} \cdot \log\left(\frac{H_1}{H_2}\right)$$

Where, r = radius of the stand pipe /Casing

$H_1$, $H_2$ = piezometric heads at times $t_1$ and $t_2$ respectively

7.13.2 The values of the coefficient of permeability 'k' so determined at the specified depth is given below :

| Test No. | Depth (m) | Permeability 'k' (cm/s) |
|---|---|---|
| 1 | 3.2 | $2.98 \times 10^{-7}$ |

## 7.14 Trial Pit

7.14.1 The grain size distributions of the soil samples collected in the Trial Pit is given below:

| TP No. | Depth (m) | Gravel (%) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|
| TP1 | 1.5 | 9 | 54 | 30 | 7 |

7.14.2 The in-situ natural densities and water contents of the soil samples collected from 0.5m and 1.5m depths in the Trial Pits are given in the table below :

| TP No. | Depth (m) | Bulk Density ($g/cm^3$) | Water Content (%) | Dry Density ($g/cm^3$) |
|---|---|---|---|---|
| TP1 | 1.5 | 1.87 | 14.3 | 1.64 |

## *8.0 DESIGN CRITERIA*

### 8.1 Design Parameters

8.1.1 The parameters required for the design of the foundation system for the proposed structures are:

a) Type of foundation to be adopted

b) Depth at which the foundations have to be laid

c) Allowable bearing pressure on the soil/rock at the foundation level.

8.1.2 On the basis of the analysis of the results of the investigations the following design parameters have been arrived at as given in the following sections.

### 8.2 Type of Foundation

8.2.1 The type of foundation depends upon the following :

a) Subsoil/rock conditions

b) Type of structure

c) Configuration of loading points

d) Loading intensity on each column at the foundation level.

8.2.2 The proposed project is a Sewage Treatment Plant consisting of Water Retaining Structures and other ancillary structures. Considering this light loads to medium loads can be anticipated on the foundations.

8.2.3 The results of the borehole investigations have indicate that the top strata of the subsoil encountered at the site is filled up soil inter mixed with cobbles, debris, etc, and extending down to depths of 2.2m and 2.7m below existing ground level at the location of boreholes BH1 and BH, and extending down to a depth of about 6.8m below existing ground level at the location of borehole BH3.

8.2.4 The virgin subsoil encountered at the site underlying the filled up soil is observed to be in a medium dense to very dense state down to the depths of rock strata.

8.2.5 The rock strata is in a completely weathered state, moderately weathered state to slightly weathered state down to the termination depth of the boreholes.

8.2.6 In view of the above, the foundations for the proposed structures can be supported over *Shallow Foundations - Isolated/Strip Footings* at the location of Boreholes BH1 and BH2 and *can be supported over Straight Bored Pile Foundations at the location of borehole BH3.*

**8.3 Depth of Foundation**

8.3.1 The depth at which the foundations should be laid, will be governed by the following criteria:

a) Presence of filled up soil/ top loose virgin soil strata, if any.

b) There should be sufficient thickness of soil above the footings/foundations so that the bearing capacity of the soil can be fully mobilised.

c) Soil / rock beyond the level of footings/foundations should have the requisite strength to support the anticipated bearing pressures on the foundations without allowing the settlements of the footings/foundations to exceed the acceptable limits.

d) Requirements of the type of structures.

8.3.2 The borehole investigations indicate that filled up soil containing boulders, debris etc,. had been encountered from the existing ground level down to depths varying from 2.2m to 6.8m below the existing ground level. Therefore the foundations for the proposed structures have to be laid on the virgin soil strata encountered below the filled up soil strata.

8.3.3 Giving due consideration to above and also as per the client requirements, the foundations of the proposed structures can be placed at various depths below the existing ground level on soil strata. Accordingly, the allowable bearing pressure will be given for various depths below existing ground level.

8.3.4 At the location of borehole BH1, rock strata had been encountered at shallow depths hence the foundations for structures at this location can rest on rock strata.

**8.4 Allowable Bearing Pressure**

8.4.1 For foundations resting in soil strata, the allowable bearing pressure on foundations is evaluated based on the following criteria :

a) Shear failure criterion using average soil data

b) Settlement criterion

(i) From N-values

(ii) From deformation modulus determined from triaxial tests.

8.4.2 Ground water table was encountered in two of the boreholes. However, as a measure of abundant precaution, full submergence has been considered, while calculating safe bearing capacity based on shear failure criterion. The water table correction factor of 0.5 has been applied.

8.4.3 On account of the observed variation in level of refusal/rock strata, the thickness of the compressible soil strata below the foundations will vary, which can cause differential settlements more than allowable. Hence, for calculation of allowable bearing pressure based on settlement criterion, the allowable settlement has been restricted to 25mm for design of foundations.

8.4.4 As the shallow foundations of the proposed structures are also to rest on rock strata, the recommendation for allowable bearing pressure for foundations resting on rock strata have been made as per the provisions of clause 5.2, Table - 2 of BIS code IS : 12070 - 1987.

8.4.5 For foundations resting on rock strata, the settlements will be well within the allowable settlement of 12mm in rock strata (refer BIS Code IS : 13063, page no.6, clause no. 5.2.8).

8.4.6 On the basis of the above analysis, the following recommendations regarding the net allowable bearing pressure are given below:

**a) For Isolated /Strip Footings**

| Borehole (BH) | Depth (m) below EGL | Net A.B.P. (t/m$^2$) for Isolated/ Strip Footings for widths of foundations | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | >6 |
| BH1 | 2.5 | 25 | 25 | 20 | 20 | 20 | 20 |
| | On Rock | 30 | 30 | 30 | 30 | 30 | 30 |
| BH2 | 3.0 | 13 | 15 | 16 | 17 | 18 | 19 |
| | 3.5 | 14 | 16 | 17 | 18 | 19 | 20 |
| | 4.5 | 17 | 19 | 20 | 21 | 23 | 24 |
| BH4 | 1.5 | 11 | 12 | 14 | 15 | 16 | 17 |
| | 2.5 | 13 | 14 | 15 | 16 | 18 | 19 |
| | 3.5 | 14 | 16 | 17 | 18 | 19 | 20 |

**b) For Square Footings**

| Borehole (BH) | Depth (m) below EGL | Net A.B.P. (t/m$^2$) for Square Footings for widths of foundations | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | >6 |
| BH1 | 2.5 | 25 | 25 | 20 | 20 | 20 | 20 |
| | On Rock | 30 | 30 | 30 | 30 | 30 | 30 |

| Borehole (BH) | Depth (m) below EGL | Net A.B.P. (t/m$^2$) for Square Footings for widths of foundations | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | >6 |
| BH2 | 3.0 | 17 | 18 | 19 | 20 | 21 | 22 |
| | 3.5 | 18 | 19 | 20 | 21 | 22 | 23 |
| | 4.5 | 20 | 21 | 22 | 23 | 24 | 25 |
| BH4 | 1.5 | 14 | 15 | 16 | 17 | 18 | 19 |
| | 2.5 | 16 | 17 | 18 | 19 | 20 | 21 |
| | 3.5 | 18 | 19 | 20 | 21 | 22 | 23 |

*EGL : Existing Ground Level*

## 8.5 Depth of Pile Foundations

8.5.1 As weathered rock strata has been encountered in the boreholes, the pile foundations should be embedded in the weathered rock strata to ensure that the pile foundations can be loaded to their safe structural capacities.

8.5.2 Accordingly, to ensure mobilization of the full safe structural capacities, the pile foundations should be *embedded minimum 3 times the diameter of the pile (3D) in weathered rock strata*.

## 8.6 Safe Pile Capacities

The Safe Pile Capacities recommended for various diameter of piles, are given below :

| Borehole (BH) | Pile Dia (mm) | Safe Pile Capacity (tons) | Safe Lateral Load Capacity (t) | |
|---|---|---|---|---|
| | | | Free Head | Fixed Head |
| BH3 | 450 | 110 | 3.2 | 8.2 |
| | 500 | 140 | 3.8 | 9.7 |
| | 600 | 190 | 5 | 13 |

## *9.0 RECOMMENDATIONS*

### 9.1 Type of Foundation

*Shallow Foundations - Isolated/Strip Footings or Straight Bored Pile Foundations*

### 9.2 Depth of Foundation & Allowable Bearing Pressure

***a) For Isolated/ Strip Footings***

| *Borehole (BH)* | *Depth (m) below EGL* | *Net A.B.P. ($t/m^2$) for Isolated/ Strip footings for widths of foundations* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *1* | *2* | *3* | *4* | *5* | *>6* |
| *BH1* | *2.5* | *25* | *25* | *20* | *20* | *20* | *20* |
| | *On Rock* | *30* | *30* | *30* | *30* | *30* | *30* |
| *BH2* | *3* | *13* | *15* | *16* | *17* | *18* | *19* |
| | *3.5* | *14* | *16* | *17* | *18* | *19* | *20* |
| | *4.5* | *17* | *19* | *20* | *21* | *23* | *24* |
| *BH4* | *1.5* | *11* | *12* | *14* | *15* | *16* | *17* |
| | *2.5* | *13* | *14* | *15* | *16* | *18* | *19* |
| | *3.5* | *14* | *16* | *17* | *18* | *19* | *20* |

*EGL : Existing Ground Level*

***b) For Square Footings***

| *Borehole (BH)* | *Depth (m) below EGL* | *Net A.B.P. ($t/m^2$) for Square footings for widths of foundations* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *1* | *2* | *3* | *4* | *5* | *>6* |
| *BH1* | *2.5* | *25* | *25* | *20* | *20* | *20* | *20* |
| | *On Rock* | *30* | *30* | *30* | *30* | *30* | *30* |
| *BH2* | *3.0* | *17* | *18* | *19* | *20* | *21* | *22* |
| | *3.5* | *18* | *19* | *20* | *21* | *22* | *23* |
| | *4.5* | *20* | *21* | *22* | *23* | *24* | *25* |
| *BH4* | *1.5* | *14* | *15* | *16* | *17* | *18* | *19* |
| | *2.5* | *16* | *17* | *18* | *19* | *20* | *21* |
| | *3.5* | *18* | *19* | *20* | *21* | *22* | *23* |

*EGL : Existing Ground Level*

## 9.3 Depth of Pile Foundation

*Embedded minimum 3 times the diameter of the pile (3D) in Weathered Rock.*

## 9.4 Safe Pile Capacities

*The Safe Pile Capacities recommended for various diameter of piles based on the safe structural capacities of the piles are given below:*

| *Borehole (BH)* | *Pile Dia (mm)* | *Safe Pile Capacity (tons)* | *Safe Lateral Load Capacity (t)* | |
|---|---|---|---|---|
| | | | *Free Head* | *Fixed Head* |
| | *450* | *110* | *3.2* | *8.2* |
| *BH3* | *500* | *140* | *3.8* | *9.7* |
| | *600* | *190* | *5.0* | *13* |

## 9.5 Construction Advisories for Shallow Foundations

9.5.1 Loose pockets of soil, wherever encountered, should be completely removed and backfilled with well compacted earth. A 15cm thick layer of 40-50mm size gravel should be laid and rammed into the backfilled earth. A layer of sand should be placed and compacted in order to fill the voids. A leveling course of lean concrete can then be laid over the gravel, and construction of foundations can be taken up subsequently.

9.5.2 Loose pockets of completely weathered rock, wherever encountered, should be completely removed and backfilled with well compacted concrete. Thereafter, the leveling course of concrete can be laid, and construction of foundations can be taken up subsequently.

9.5.3 Rock Strata has been encountered at depths varying from 3.2m to 7.8m. Hence, during excavation for foundations, moderately weathered to slightly weathered rock is likely to be encountered and further excavation by ordinary manual means, using crowbar and pickaxe may not be possible. This should be taken into account while planning the work.

9.5.4 To safely adopt the recommended net allowable bearing pressures the foundations should be ensured to be resting fully on Moderately Weathered Rock to Slightly Weathered Rock.

## 9.6 Deep Excavation

The top strata of subsoil encountered at the site is generally loose filled-up soil down to about 0.8m depth below existing ground level. The virgin subsoil encountered at the site is observed to be in a medium dense to very dense state. Ground water table was not encountered at shallow depths in the boreholes. However, adequate precautions must be taken against collapse of the sides of the basement excavation and foundation pits, especially during rainy season.

## 9.7 Appendix

9.7.1 An appendix sheet showing the typical analysis of the allowable bearing pressure has been given in Appendix-A of this report.

9.7.2 An appendix sheet showing the typical analysis of the Structural Capacity of Pile has been given in Appendix-B of this report.

9.7.3 An appendix sheet showing the typical analysis of the Lateral Pile Load Capacity has been given in Appendix-C of this report.

9.7.4 A list of IS Codes referred for providing the recommendations and that which might be required to implement the same is also enclosed in this report in Appendix - D.

## 9.8 Note

The recommendations given in this report have been arrived at on the basis of design parameters which have been judiciously adopted by giving due consideration to the results of field and laboratory investigations as well as NAGADI's experience of over four decades in working in various types of soil and rock conditions all over India.

## *10.0 LIMITATIONS*

This soil investigations have been carried out at selected locations in the site chosen by the clients so as to represent the entire site. The recommendations provided in this report are hence valid only for these test locations. However, if there is any change in subsoil conditions and properties at places between or beyond chosen test locations, fresh investigations will have to be carried out at such location.

Dr. N Santosh Rao
*Technical Director*
***for Nagadi Consultants Pvt. Ltd.***

## ANALYSIS FOR ALLOWABLE BEARING PRESSURE

*Location : Borehole BH2*

**Data**

(i) Soil Properties :

c (kg/cm$^2$) = 0.14 N = 27° ( (g/cm$^3$) = 1.95

(ii) Depth of Foundation, D (m) = 3.5m below existing ground level

(iii) Allowable Settlement, s (mm) = 25

**Shear Failure Criterion (Ref. IS : 6403)**

$N_c'$ = 16.88 $N_q'$ = 7.82 $N_(' = 7.12 $R_w$ =0.5 $R_w'$ =0.5

***Safe Bearing Capacity for Strip Footing :***

$$q_s = \frac{1}{3}\cdot\left(c\cdot Nc + 0.5.\gamma\cdot B\cdot N_\gamma Rw + \gamma\cdot D\cdot N_q.\ R_w'\right) - \gamma\cdot D$$

| B (m) | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $q_s$ (t/m$^2$) | 14.5 | 15.7 | 16.8 | 18.0 | 19.2 | 20.3 |

***Safe Bearing Capacity for Square Footing :***

$$q_s = \frac{1}{3}\cdot\left(1.3\cdot c\cdot Nc + 0.8\cdot 0.5.\gamma\cdot B\cdot N_\gamma Rw + 1.2\cdot\gamma\cdot D\cdot N_q.\ R_w'\right) - \gamma\cdot D$$

| B (m) | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $q_s$ (t/m$^2$) | 18.4 | 19.4 | 20.3 | 21.2 | 22.1 | 23.1 |

**Settlement Criterion (Ref. IS : 8009)**

***(i) From N Values***

| B (m) | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| H (m) | 2 | 2 | 2 | 2 | 2 | 2 |
| $N_{av}$ | 66 | 66 | 66 | 66 | 66 | 66 |
| $q_a$ (t/m$^2$) | 73.7 | 57.7 | 52.8 | 50.4 | 49.0 | 48.1 |

*(ii)* ***From Triaxial Compression Tests :*** $q_a = \dfrac{s \cdot E}{0.7 \cdot H}$

| | | | | | | |
|---|---|---|---|---|---|---|
| B (m) | 1 | 2 | 3 | 4 | 5 | 6 |
| H (m) | 2 | 2 | 2 | 2 | 2 | 2 |
| E ($t/m^2$) | 1200 | 1400 | 1600 | 1800 | 2000 | 2100 |
| $q_a$ ($t/m^2$) | 21.4 | 25.0 | 28.5 | 32.1 | 35.7 | 37.5 |

**For Strip Footings:**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **ADOPT** | **B (m)** | **1** | **2** | **3** | **4** | **5** | **6** |
| | **q ($t/m^2$)** | **14** | **16** | **17** | **18** | **19** | **20** |

**For Square Footings:**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***ADOPT*** | ***B (m)*** | **1** | **2** | **3** | **4** | **5** | **6** |
| | **q ($t/m^2$)** | **18** | **19** | **20** | **21** | **22** | **23** |

**Note : $q_s$ and $q_a$ are NET VALUES, Weight of backfill etc. need not be added to the loading except in case of filling above original G.L.s**

**Appendix - B**

## TYPICAL CALCULATIONS FOR STRUCTURAL CAPACITY OF PILE

$$Q = F_{cc} \cdot (A_P - A_S) + F_{sc} \cdot A_s$$

Where, $F_{cc}$ = Allowable Compressive Stress in concrete (IS 2911) = 25% of $f_{ck}$

$f_{ck}$ = Characteristic strength of concrete = 250kg/cm²

$A_P$ = Cross sectional area of the concrete

= ($\pi$ x $d^2$ / 4) = 1590.43 cm²

d = Diameter of the pile = 45 cm

$A_S$ = Area of steel reinforcement = 0.4% of concrete area = 6.36 cm²

$F_{sc}$ = Allowable Compressive Stress in steel (IS 456) = 1900 kg/cm²

Q = 62.5 (1590.43 - 6.36) + 1900 x 6.36

= 99004.37 + 12084

= 111088.3 kg

**Q = 111.08 tons Say, 110 tons.**

## TYPICAL CALCULATION OF LATERAL PILE LOAD CAPACITY

## (As per IS : 2911 (Part1/Sec2) - 2010)

### C.1 Methodology

C.1.1 A typical calculation for the lateral pile load capacity has been given hereunder for a pile of diameter 'D' = 450mm.

C.1.2 For determining the lateral pile load capacity, the depth of fixity of the piles or in other words, the equivalent cantilever length of the pile, has to be first determined. The depth of fixity is determined based on the modulus of horizontal subgrade reaction $0_h$ value which in turn is considered based on the relative density/ soil consistency of the soil as observed in the boreholes conducted, as per table 3 of Annex - C of the BIS code IS:2911(part1/sec2).

C.1.3 Considering that the soil in the top one-half length of the pile is on an average in a loose to medium dense state/ soft to medium stiff state, the modulus of horizontal subgrade reaction can be taken as 0.6 kg/cm$^3$ applicable for submerged condition, as per table 1 of Annex - C of the BIS code IS:2911(part1/sec2).

### C.2 Evaluation of Depth of Fixity

C.2.2 The stiffness factor T is calculated as per C - 2.3.1 of Annex - C of the BIS code IS:2911(part1/sec2) , as given below:

$$Stiffness.\ factor = T = 5\sqrt{\frac{EI}{\eta_h}}$$

***Stiffness factor = T = 1.56m.***

C.2.3 Hence, the equivalent cantilever length or in other words the depth of fixity ($L_e$) of the pile works out to be based on stiffness factor (T) and the plot given in fig.4 in C - 3 of Annex - C of the BIS code IS:2911(part1/sec2)

$L_e = 1.9 \times T = 1.9 \times 1.51 = 2.9m$ *(for free head condition)*

$L_e = 2.2 \times T = 2.2 \times 1.51 = 3.4m$ *(for fixed head condition)*

C.1.4 The lateral pile load capacity is then determined as the horizontal force required for causing the allowable horizontal deflection of the pile head when considering the pile as a cantilever.

C.1.5 For calculation purposes, the concrete of pile has been considered to be of M30 grade.

C.1.6 For the determination of the lateral pile load capacity, the allowable horizontal deflection of the pile head has been considered as 5mm based on the provisions of clause 7.4 of BIS code IS:2911 (Part4) - 1985.

## C.3 Determination of Lateral Pile Load Capacity

C.3.1 The horizontal deflection of the pile head, is determined by the following equations :

$$y = \frac{Q_L \cdot L_e^3}{3 \cdot E \cdot I}$$ *(for free head condition)*

$$y = \frac{Q_L \cdot L_e^3}{12 \cdot E \cdot I}$$ *(for fixed head condition)*

C.3.2 The flexural rigidity 'EAI' of the pile section has to be then determined by taking into account the flexural rigidity provided by the reinforcement. For this purpose, the moment of inertia 'I' is determined by taking into account the area of reinforcement along with the appropriate value of modular ratio 'm'.

C.3.3 The elastic modulus of concrete is determined as :

$$E = 5000 \cdot \sqrt{f_{ck}}$$

Where $f_{ck}$ = characteristic strength of concrete = 30N/mm$^2$

Hence, E = 30,000 N/mm$^2$ or 273,861 kg/cm$^2$

C.3.4 The moment of inertia of the pile section is determined as :

$$I = \frac{\pi \cdot d^4}{64}$$

Hence, I = 201288.9 cm$^4$

C.3.2 Considering an allowable horizontal deflection of the pile head of 5mm, the lateral pile load capacity works out to be :

***$Q_L$ = 3.2 tons*** *(for free head condition)*

***$Q_L$ = 8.2 tons*** *(for fixed head condition).*

**Appendix -D**

## LIST OF IS CODES

### Field Investigation

| | | | |
|---|---|---|---|
| 1. | IS : 1892 - 2021 | : | Code of practice for sub surface investigations for foundations (Second revision). |
| 2. | IS : 2131 - 1981 | : | Method of Standard Penetration Tests for soils (First revision). |
| 3. | IS : 2132 - 1986 | : | Code of practice for thin walled tube sampling of soils (Second revision). |
| 4. | IS: 3043 -1987 | : | Code of practice for earthing (First revision) |
| 5. | IS : 11315 - 1985 (Part 11) | : | Method for the quantitative descriptions of discontinuities in rock masses |
| 6. | IS : 11315 - 1995 (Part 12) | : | Quantitative description of discontinuities in rock mass methods. |
| 7. | IS: 5529 (Part1) - 1985 | : | Code of practice for in-situ permeability tests. |

### Laboratory Tests

| | | | |
|---|---|---|---|
| 1. | IS : 2720 - 1983 (Part 1) | : | Methods of test for soils: Preparation of dry soil samples for various tests (Second revision). |
| 2. | IS : 2720 - 1980 (Part 2) | : | Method of test for soils: Determination of water content (Second revision) Amendment 1. |
| 3. | IS : 2720 - 1985 (Part 4) | : | Method of test for soils : Grain size analysis (Second revision). |
| 4. | IS : 2720 (Part 8) -1983 | : | Determination of water content - dry density relation using heavy compaction(First revision). |
| 5. | IS : 2720 - 1985 (Part 5) | : | Method of test for soils : Determination of liquid and plastic limit (Second revision). |

| | | | |
|---|---|---|---|
| 6. | IS 2720 - 1981 Part 12 | : | Method of tests for soils : Determination of shear strength parameters using triaxial apparatus. |
| 7. | IS 8764 - 1998 | : | Method for determination of point load strength index of rocks (First Revision) |
| 8. | IS : 13030 : 1991 | : | Method of test for laboratory determination of water content, porosity, density and related properties of rock material. |

**Foundation Construction**

| | | | |
|---|---|---|---|
| 1. | IS : 1080 - 1986 | : | Code of practice for design and construction of shallow foundations on soils (other than raft, ring and shell) (Second revision). |
| 2. | IS : 1904 - 1986 | : | Code of practice for design and construction of foundation in soils : General requirements (Third revision). |
| 3. | IS : 6403 - 1981 | : | Code of practice for determination of bearing capacity of shallow foundations : First revision (Amendment 1). |
| 4. | IS : 8009 - 1976 (Part 1) | : | Code of practice for calculation of settlements of foundations : Shallow foundations subject to symmetrical static vertical loads (Amendment 2). |
| 5. | IS : 12070 - 1987 | : | Code of practice for design and construction of Shallow foundations on Rocks. |
| 6. | IS : 13063 - 1991 | : | Structural Safety of Buildings on Shallow Foundations on Rocks. |
| **7.** | IS : 2911 - 2010 (Part1/sec2) | : | Design and construction of pile foundations - Bored Cast In-situ concrete piles. |

# TABLES

NAGADI

| SOIL PROFILE | | Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B.H. Location : | Water Table : Nil | | | | Term. Depth : 8.2m | | | | B.H. No.: 1 | | |
| ■ N - Value | Depth (m) | Soil Description | Grain Size Analysis | | | | Atterberg Limits | | In-situ properties | | Triaxial Test | | |
| | | | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Density $(\gamma_b$ g/cm$^3$) | Water Cont (%) | Type | c (kg/cm$^2$) | N ($^o$) |
| | 0.0 | Existing ground level | | | | | | | | | | | |
| | 0.5 | Filled up soil : From 0.0m to 2.2m depth | | | | | | | | | | | |
| | 0.9 | (Filled up soil) Brown with grey silty sand with clay and traces of gravel | | | | | | | 1.83 | 13.7 | | | |
| 9 | 1.5 | (Filled up soil) Brown with grey silty sand with clay and traces of gravel | 3 | 81 | 11 | 5 | | | | | | | |
| 22 | 2.5 | Brownish grey clayey silty sand | 0 | 52 | 32 | 16 | 30 | 21 | | | | | |
| 31/ 5cm | 3.0 | Yellowish white clayey silty sand | 0 | 49 | 28 | 23 | 36 | 23 | | | | | |
| | 3.2 | Refusal strata (22 blows for 3cm penetration) | | | | | | | | | | | |
| | | Note : 1) ■N-Value (Observed)<br>2) $\gamma_b$ : Bulk Density | | | | | | | | | | | |

# ROCK PROFILE

Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru

B.H. Size : | Water Table (m): Nil | Term. Depth (m): 8.2m | B.H. No. : 1

| Depth (m) | Strata Description | No. of Core Pieces of Size (cm) | | | | Core Recovery (%) | | | | | | RQD (%) | Run Time (min) | Unit Weight (g/cm$^3$) | Porosity (%) | Water Absorption (%) | Unconfined Compressive Strength (kg/cm$^2$) | Point Load Strength (kg/cm$^2$) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | 10-25 | 25-75 | >75 | 20 | 40 | 60 | 80 | 100 | | | | | | | | | |
| 3.2 | - | | | | | | | | | | | | | | | | | | |
| | Grey granitic gneiss/Highly weathered rock | 3 | 0 | 0 | 0 | | | | | | 9 | 0 | 60 | 1.98 | 2.54 | 2.03 | | 296 | |
| 5.0 | - | | | | | | | | | | | | | | | | | | |
| | White with grey granitic gneiss/Completely weathered rock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | | | | | | |
| 6.5 | -23/3cm | | | | | | | | | | | | | | | | | | |
| | Blackish grey granitic gneiss/ Highly weathered rock | 3 | 0 | 0 | 0 | | | | | | 11 | 0 | 80 | 2.62 | 1.25 | 1.01 | | 330 | |
| 8.2 | - | | | | | | | | | | | | | | | | | | |

| SOIL PROFILE | | | Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | B.H. Location : | Water Table : 4m | | | | Term. Depth : 10.7m | | | | B.H. No.: 2 | | |
| ■ N - Value | Depth (m) | Soil Description | Grain Size Analysis | | | | | Atterberg Limits | | In-situ properties | | Triaxial Test | | |
| | | | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | | Liquid (%) | Plastic (%) | Density ($\gamma_b$ g/cm$^3$) | Water Cont (%) | Type | c (kg/cm$^2$) | N ($^o$) |
| | 0.0 | Existing ground level | | | | | | | | | | | | |
| | 0.5 | Filled up soil : From 0.0m to 2.7m depth | | | | | | | | | | | | |
| 28 | 0.9 | Filled up soil (Reddish brown clayey silty sand with gravel | 7 | 57 | 23 | 13 | | | | | | | | |
| | 1.5 | Filled up soil | | | | | | | | | | | | |
| | 3.0 | Brownish grey silty clayey sand | | | | | | | | 1.93 | 14.7 | CD | 0.15 | 26 |
| 22 | 3.5 | Brownish grey silty clayey sand | 0 | 42 | 27 | 31 | | 38 | 23 | | | | | |
| | 4.5 | Brown with bluish grey clayey silty sand | | | | | | | | 1.94 | 12.6 | CD | 0.13 | 28 |
| 59 | 5.0 | Yellowish white with grey silty sand with clay and gravel | | | | | | | | | | | | |
| 43/ 5cm | 5.5 | Yellowish white with grey silty sand with clay and gravel | 20 | 62 | 12 | 6 | | | | | | | | |
| | 5.7 | Refusal strata (21 blows for 3cm penetration) | | | | | | | | | | | | |
| | | Note : 1) ■N-Value (Observed)<br>2) $\gamma_b$ : Bulk Density | | | | | | | | | | | | |

# ROCK PROFILE

Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru

B.H. Size : | Water Table (m): 4m | Term. Depth (m): 10.7m | B.H. No. : 2

| Depth (m) | Strata Description | No. of Core Pieces of Size (cm) | | | | Core Recovery (%) | | | | | | RQD (%) | Run Time (min) | Unit Weight ($g/cm^3$) | Porosity (%) | Water Absorption (%) | Unconfined Compressive Strength ($kg/cm^2$) | Point Load Strength ($kg/cm^2$) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | 10-25 | 25-75 | >75 | 20 | 40 | 60 | 80 | 100 | | | | | | | | | |
| 5.7 | - | | | | | | | | | | | | | | | | | | |
| | Grey granitic gneiss/Highly weathered rock | 4 | 0 | 0 | 0 | | | | | | 18 | 0 | 85 | 1.91 | 3.01 | 2.51 | - | - | |
| 7.2 | - | | | | | | | | | | | | | | | | | | |
| | Grey granitic gneiss/Highly weathered rock | 7 | 0 | 0 | 0 | | | | | | 19 | 0 | 90 | | | | | | |
| 8.7 | - | | | | | | | | | | | | | | | | | | |
| | Blackish grey granitic gneiss/Highly weathered rock | 4 | 0 | 0 | 0 | | | | | | 17 | 0 | 50 | | | | | | |
| 9.7 | - | | | | | | | | | | | | | | | | | | |
| | Blackish grey granitic gneiss/Highly weathered rock | 3 | 0 | 0 | 0 | | | | | | 19 | 0 | 60 | 2.21 | 1.68 | 1.32 | - | 259 | |
| 10.7 | - | | | | | | | | | | | | | | | | | | |

| SOIL PROFILE | | | Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | B.H. Location : | Water Table : 8.2m | | | | Term. Depth : 12.8m | | | | B.H. No.: 3 | |
| ■ N - Value | Depth (m) | Soil Description | Grain Size Analysis | | | | Atterberg Limits | | In-situ properties | | Triaxial Test | | |
| | | | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Density ($\gamma_b$ g/cm$^3$) | Water Cont (%) | Type | c (kg/cm$^2$) | N ($^o$) |
| | 0.0 | Existing ground level | | | | | | | | | | | |
| | 1.3 | Filled up soil : From 0.0m to 6.8m depth | | | | | | | | | | | |
| 14 | 1.5 | (Filled up soil) Reddish brown silty clayey sand with gravel | 6 | 66 | 12 | 16 | | | | | | | |
| | 2.5 | (Filled up soil) Reddish brown silty clayey sand | | | | | | | 1.92 | 11.3 | CD | 0.12 | 26 |
| 28/ 5cm | 3.0 | Filled up soil (Brown) | | | | | | | | | | | |
| 20/ 3cm | 4.5 | Filled up soil (Boulders) | | | | | | | | | | | |
| 22/ 3cm | 6.0 | Filled up soil (Boulders) | | | | | | | | | | | |
| | 7.5 | Brownish yellow with white clayey silty sand | 0 | 66 | 20 | 14 | 25 | NP | | | | | |
| | 7.8 | Refusal strata (21 blows for 3cm penetration) | | | | | | | | | | | |
| | | Note : 1) ■N-Value (Observed)<br>2) $\gamma_b$ : Bulk Density | | | | | | | | | | | |

# ROCK PROFILE

Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru

B.H. Size : | Water Table (m): 8.2m | Term. Depth (m): 12.8m | B.H. No. : 3

| Depth (m) | Strata Description | No. of Core Pieces of Size (cm) | | | | Core Recovery (%) | | | | | | RQD (%) | Run Time (min) | Unit Weight (g/cm$^3$) | Porosity (%) | Water Absorption (%) | Unconfined Compressive Strength (kg/cm$^2$) | Point Load Strength (kg/cm$^2$) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | 10-25 | 25-75 | >75 | 20 | 40 | 60 | 80 | 100 | | | | | | | | | |
| 7.8 | - | | | | | | | | | | | | | | | | | | |
| | Brown granitic gneiss/Completely weathered rock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45 | | | | | | |
| 9.0 | -25/3cm | | | | | | | | | | | | | | | | | | |
| | Blackish grey granitic gneiss/Highly weathered rock | 3 | 0 | 0 | 0 | | | | | | 9 | 0 | 35 | | | | | | |
| 10.0 | - | | | | | | | | | | | | | | | | | | |
| | Blackish grey granitic gneiss/Highly weathered rock | 3 | 0 | 0 | 0 | | | | | | 15 | 0 | 50 | 2.21 | 1.95 | 1.36 | - | 396 | |
| 11.5 | - | | | | | | | | | | | | | | | | | | |
| | Grey granitic gneiss/Slightly weathered rock | 0 | 1 | 1 | 0 | | | | | | 52 | 52 | 110 | 2.82 | 0.10 | 0.01 | 1025 | 1278 | |
| 12.8 | - | | | | | | | | | | | | | | | | | | |

| SOIL PROFILE | | | Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | B.H. Location : | Water Table : Nil | | | | Term. Depth : 10.8m | | | | B.H. No.: 4 | | |
| ■ N - Value | Depth (m) | Soil Description | Grain Size Analysis | | | | | Atterberg Limits | | In-situ properties | | Triaxial Test | | |
| | | | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | | Liquid (%) | Plastic (%) | Density ($\gamma_b$ g/cm$^3$) | Water Cont (%) | Type | c (kg/cm$^2$) | N ($^o$) |
| | 0.0 | Existing ground level | | | | | | | | | | | | |
| | 0.5 | Reddish brown clayey silty sand | | | | | | | | | | | | |
| 12 | 0.9 | Reddish brown with yellow clayey silty sand | 0 | 48 | 27 | 25 | | 36 | 22 | | | | | |
| | 1.5 | Reddish brown with yellow clayey silty sand | | | | | | | | 1.92 | 15.2 | CD | 0.16 | 24 |
| 22 | 2.5 | Reddish brown with yellow clayey silty sand | 0 | 46 | 27 | 27 | | | | | | | | |
| | 3.5 | Yellow with grey clayey silty sand | | | | | | | | 1.97 | 10.4 | CD | 0.13 | 29 |
| | 4.5 | Yellow with dark grey clayey silty sand | 0 | 49 | 35 | 16 | | 32 | 20 | | | | | |
| | 4.8 | Refusal strata (22 blows for 3cm penetration) | | | | | | | | | | | | |
| | | Note : 1) ■N-Value (Observed)<br>2) $\gamma_b$ : Bulk Density | | | | | | | | | | | | |

# ROCK PROFILE

Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru

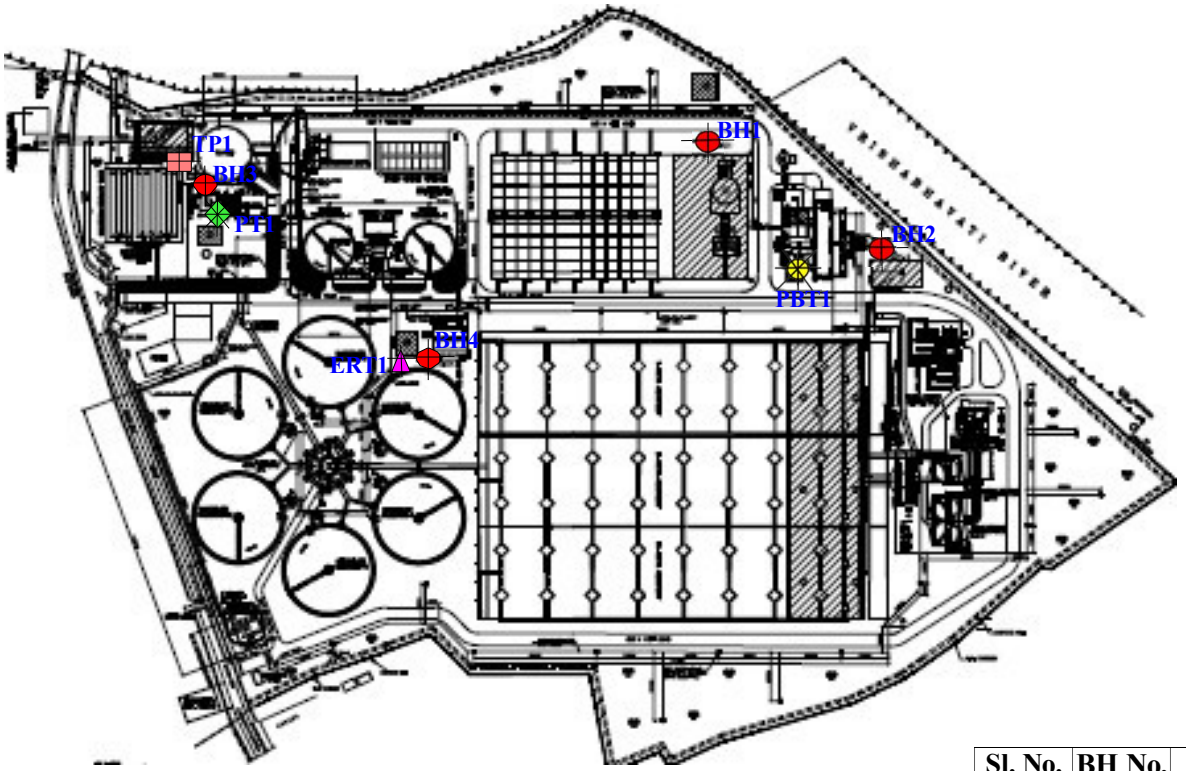
B.H. Size : | Water Table (m): Nil | Term. Depth (m): 10.8m | B.H. No. : 4

| Depth (m) | Strata Description | No. of Core Pieces of Size (cm) | | | | Core Recovery (%) | | | | | | RQD (%) | Run Time (min) | Unit Weight (g/cm$^3$) | Porosity (%) | Water Absorption (%) | Unconfined Compressive Strength (kg/cm$^2$) | Point Load Strength (kg/cm$^2$) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | 10-25 | 25-75 | >75 | 20 | 40 | 60 | 80 | 100 | | | | | | | | | |
| 4.8 | - | | | | | | | | | | | | | | | | | | |
| | Brown granitic gneiss/Completely weathered rock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | | | | | | |
| 6.3 | -23/3cm | | | | | | | | | | | | | | | | | | |
| | Brown granitic gneiss/Completely weathered rock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 | | | | | | |
| 7.8 | -24/3cm | | | | | | | | | | | | | | | | | | |
| | White with grey Quartz/Highly weathered rock | 2 | 0 | 0 | 0 | | | | | | 7 | 0 | 100 | 2.51 | 1.01 | 0.89 | - | 349 | |
| 9.3 | - | | | | | | | | | | | | | | | | | | |
| | White with grey Quartz/Highly weathered rock | 2 | 0 | 0 | 0 | | | | | | 10 | 0 | 120 | 2.63 | 0.96 | 0.65 | - | 452 | |
| 10.8 | - | | | | | | | | | | | | | | | | | | |

| SOIL PROFILE | | Project : Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B.H. Location : | Water Table : Nil | | | | Term. Depth : 1.5m | | | | T.P. No.: 1 | | |
| ■ N - Value | Depth (m) | Soil Description | Grain Size Analysis | | | | Atterberg Limits | | In-situ properties | | Triaxial Test | | |
| | | | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Liquid (%) | Plastic (%) | Density ($\gamma_b$ g/cm$^3$) | Water Cont (%) | Type | c (kg/cm$^2$) | N ($^o$) |
| | 0.0 | Existing ground level | | | | | | | | | | | |
| | 0.3 | Filled up soil : From 0.0m to 1.5m depth | | | | | | | | | | | |
| | 0.8 | Filled up soil (Brownish red silty sand with clay and gravel | | | | | | | | | | | |
| | 1.5 | Filled up soil (Reddish brown silty sand with clay and gravel) | 9 | 54 | 30 | 7 | 26 | NP | 1.87 | 14.3 | | | |
| | | Note : $\gamma_b$ : Bulk Density | | | | | | | | | | | |

# FIGURES

NAGADI




**Schematic Site Plan**

| Sl. No. | BH No. | East | North |
|---|---|---|---|
| 1 | 1 | 3034.742 | 2277.968 |
| 2 | 2 | 3120.324 | 2288.512 |
| 3 | 3 | 2882.126 | 2141.405 |
| 4 | 4 | 3001.909 | 2139.681 |

Legend

: Boreholes

: Trial Pit

: Field Permeability Test

: Field Percolation Test

: Earth Resistivity Test

Note : Sketch Not To Scale

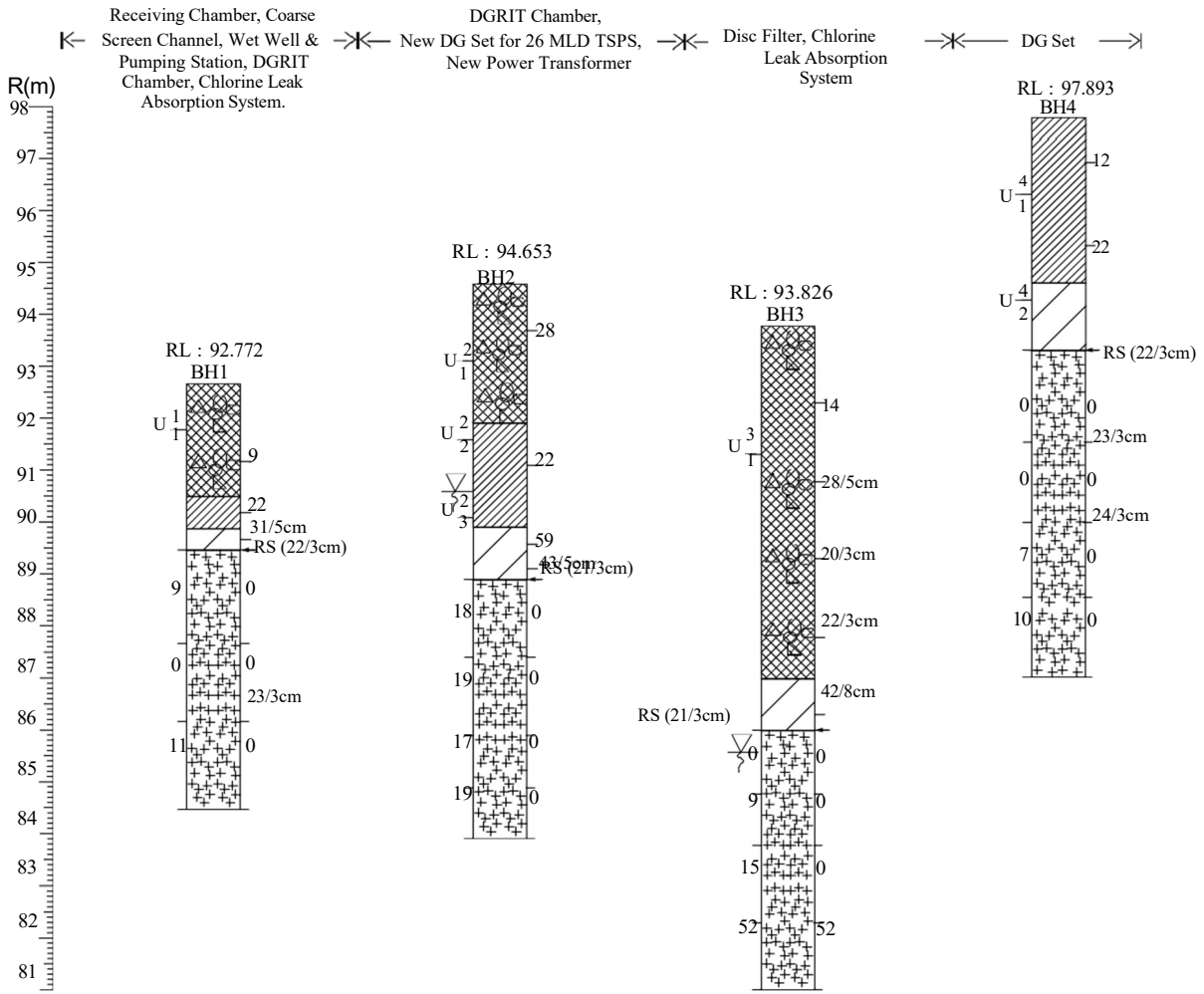
NAGADI

Nagadi Consultants Pvt. Ltd.,
Geotechnical Consultants,
Bangalore.

Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant & Capacity Augmentation to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru.

Job No.G(B)12788

Sheet No. 1




Compiled Soil / Rock Profile

## Legend

### *Stratum - I*

Filled up soil with boulders, debris, etc., (Brown with grey to reddish brown clayey silty sand with gravelto silty sand with clay)
[Gravel (3-7%) Sand (57-81%)] Silt (11-23%) Clay (5-16%)

### *Stratum - II*

Brownish grey to reddish brown with yellow clayey silty sand to silty clayey sand [Gravel (0%) Sand (42-52%) Silt (27-32%) Clay (16-31%)]

### *Stratum - III*

Yellowish white with grey to brownish yellow with white clayey silty sand to silty sand with clay and gravel
[Gravel (0-20%) Sand (49-62%) Silt (12-35%) Clay (6-23%)]

### *Stratum - IV*

Blackish Grey and White granitic gneiss/Quartz Completely Weathered rock, Moderately weathered rock to Slightly weathered rock

52 : Core recovery (%)

52 : RQD (%)

R.L. : Reduced Level

7 : N – value (Observed)

U 1/1 : First Undisturbed Sample in Borehole No. 1

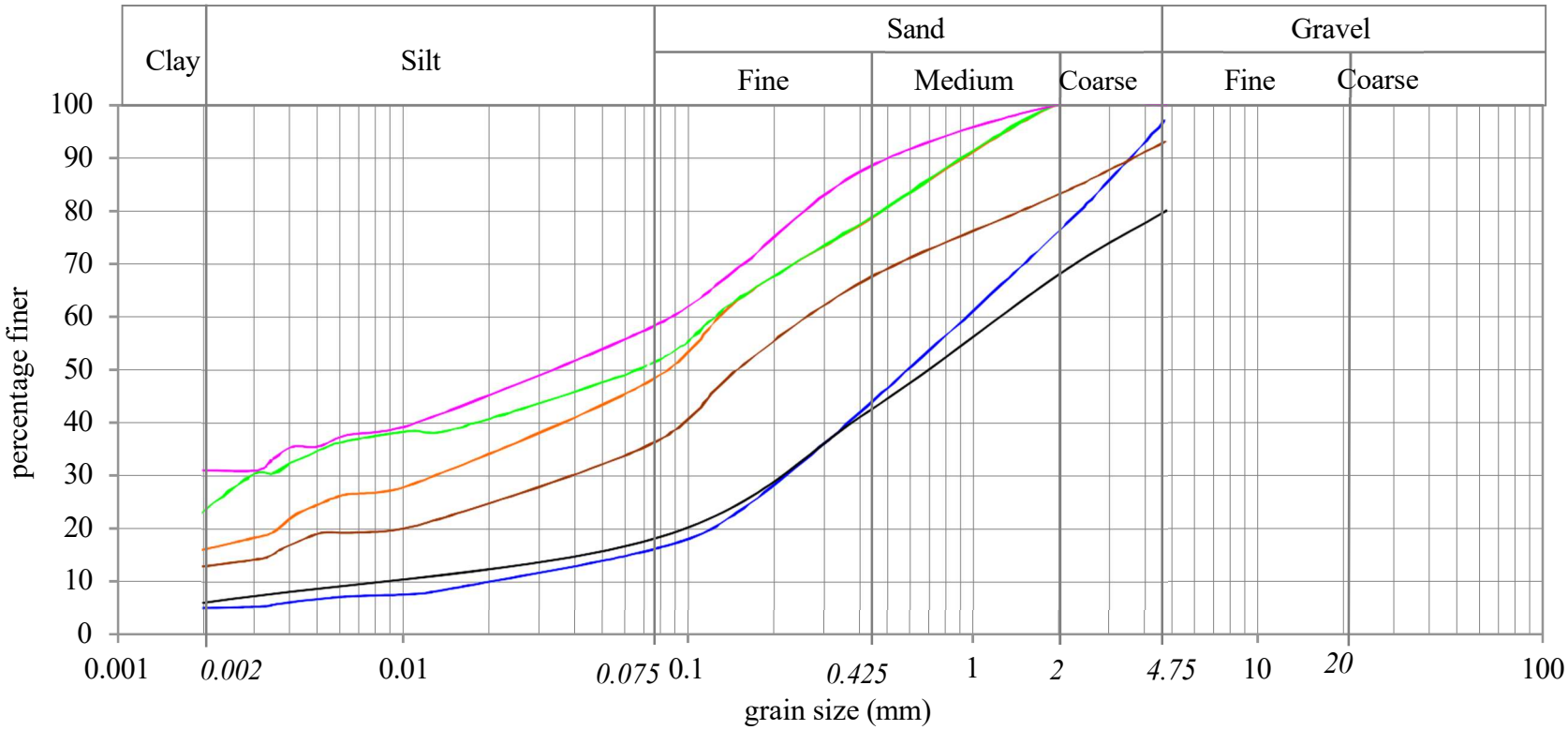
: Water table

Note : BH1 & BH4 Water table not encountered

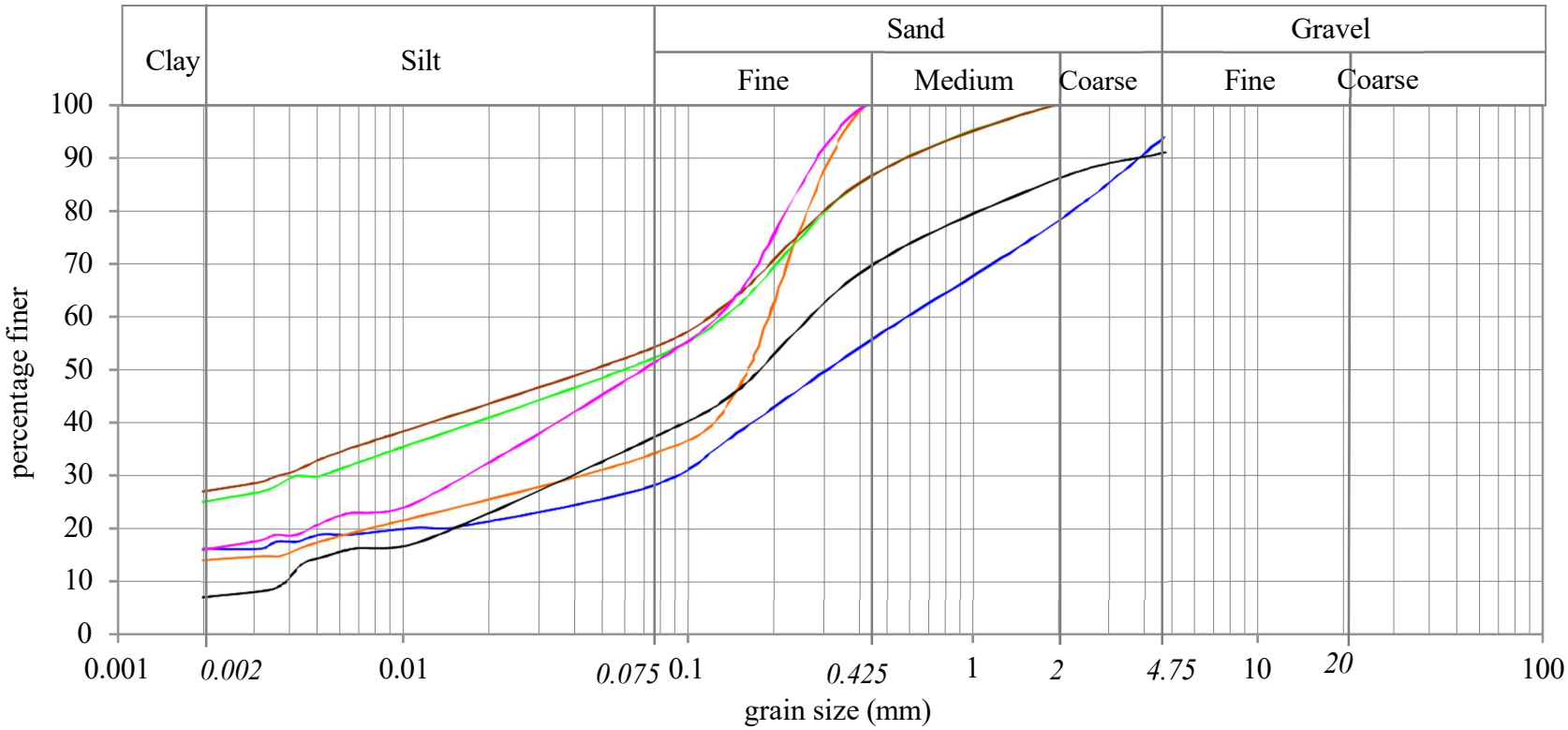
RS : Refusal Strata

20/3cm : 20 blows for 3cm penetration

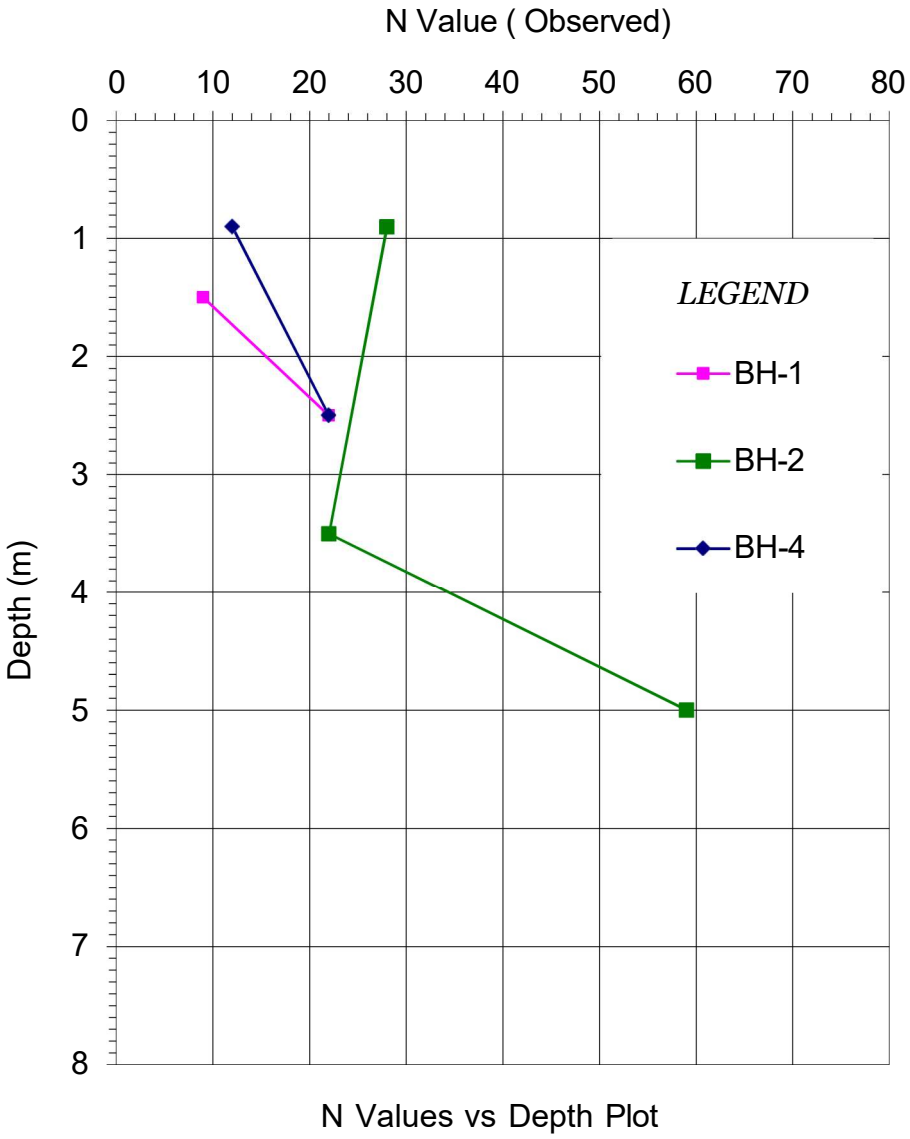
| | | | |
|---|---|---|---|
| NAGADI | Nagadi Consultants Pvt. Ltd., Geotechnical Consultants, Bangalore. | Proposed Upgradation of Existing 75 MLD Capacity Sewage Treatment Plant & Capacity Augmentation to 100MLD Sewage Treatment Plant at Mailasandra, Bengaluru. | G(B)12788 |
| | | | Sheet No. 2 |




| Line Style | Bore hole | Depth (m) | Description | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | $d_{60}$ | $d_{10}$ | U |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1.5 | Brown with grey silty sand with clay and traces of grave | 3 | 81 | 11 | 5 | 0.95 | 0.02 | 47.5 |
| | 1 | 2.5 | Brownish grey clayey silty sand | 0 | 52 | 32 | 16 | 0.14 | - | - |
| | 1 | 3 | Yellowish white silty sand with clay | 0 | 49 | 28 | 23 | 0.13 | - | - |
| | 2 | 0.9 | Reddish brown clayey silty sand with gravel | 7 | 57 | 23 | 13 | 0.26 | - | - |
| | 2 | 3.5 | Brownish grey silty clayey sand | 0 | 42 | 27 | 31 | 0.09 | - | - |
| | 2 | 5.5 | Yellowish white with grey silty sand with clay and grave | 20 | 62 | 12 | 6 | 1.13 | 0.0053 | 213.2 |
| | | | | | | | | | | |
| | | | | | | | | | | |



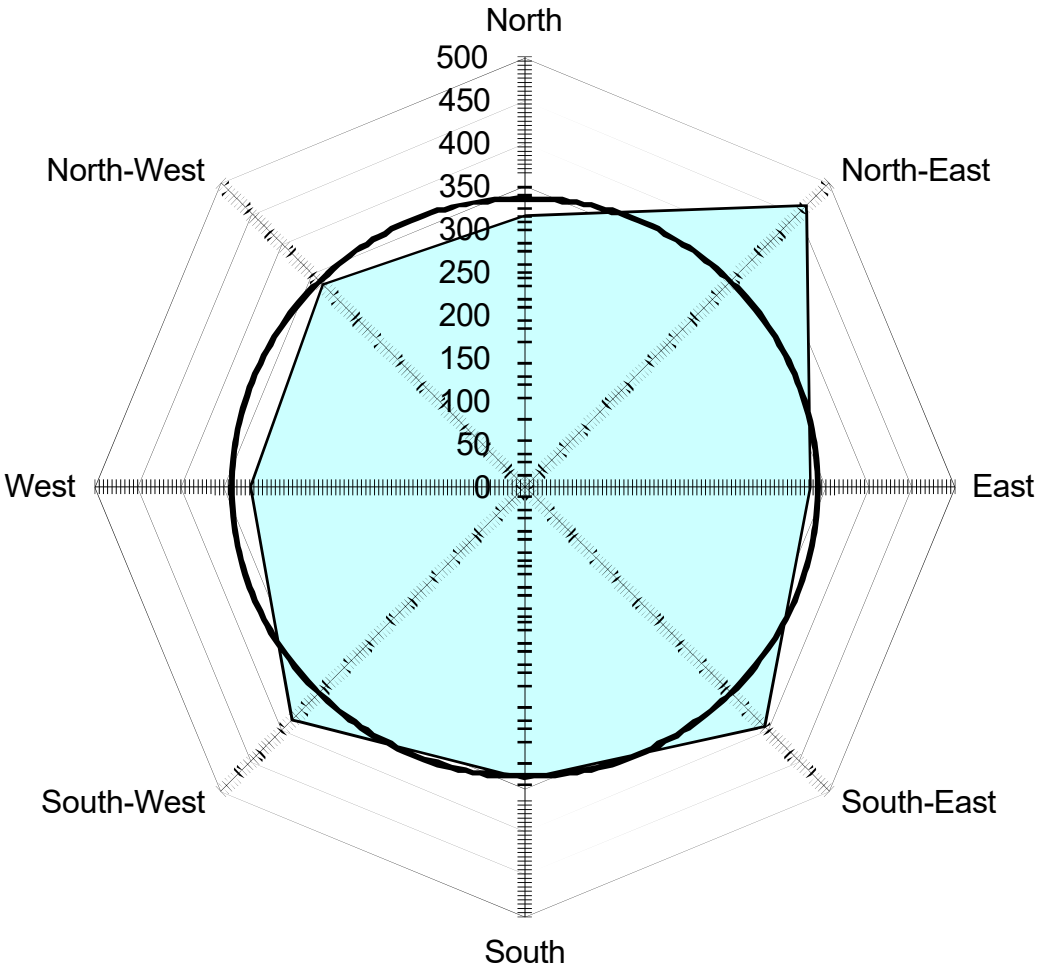

| Line Style | Bore hole | Depth (m) | Description | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | $d_{60}$ | $d_{10}$ | U |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 1.5 | Reddish brown silty clayey sand with gravel | 6 | 66 | 12 | 16 | 0.55 | - | - |
| | 3 | 7.5 | Brownish yellow with white clayey silty sand | 0 | 66 | 20 | 14 | 0.19 | - | - |
| | 4 | 0.9 | Reddish brown with yellow clayey silty sand | 0 | 48 | 27 | 25 | 0.15 | - | - |
| | 4 | 2.5 | Reddish brown with yellow clayey silty sand | 0 | 46 | 27 | 27 | 0.14 | - | - |
| | 4 | 4.5 | Yellow with dark grey clayey silty sand | 0 | 49 | 35 | 16 | 0.15 | - | - |
| | TP1 | 1.5 | Reddish brown silty sand with clay and gravel | 9 | 54 | 30 | 7 | 0.29 | 0.003 | 96.7 |
| | | | | | | | | | | |
| | | | | | | | | | | |




N Values vs Depth Plot

G(B)12788

*Resistivity = radius of equivalent circle = 339.88 Ohm-m*

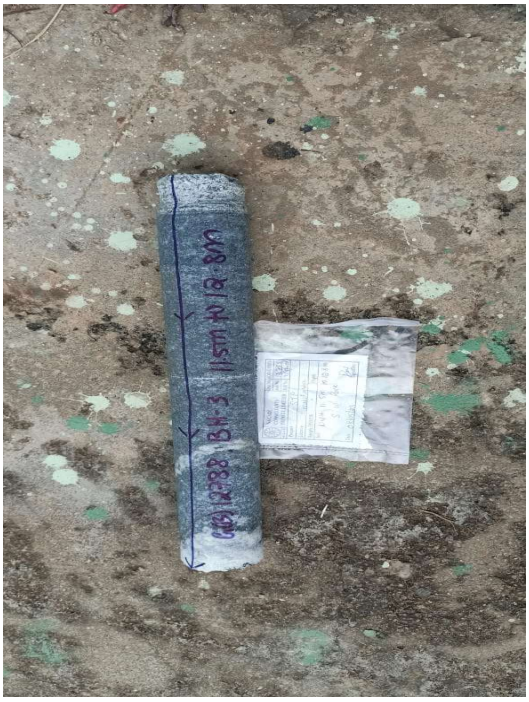



Polar Diagram

Earth Resistivity Test - 1

***PHOTOS***

G(B)12788


G(B)12788 BH-3 1.5m to 12.0m

NAGADI CONSULTANTS PRIVATE LIMITED
NEW DELHI - BANGALORE - CHENNAI - SECUNDERABAD